The closer they are, the more they interfere

Rose, Sebastian Benjamin; Aristei, Sabrina; Melinger, Alissa; Abdel Rahman, Rasha

Published in:
Journal of Experimental Psychology: Learning, Memory, and Cognition

DOI:
10.1037/xlm0000592

Publication date:
2019

The closer they are, the more they interfere: Semantic similarity of word distractors increases competition in language production

Sebastian Benjamin Rose[1]

Sabrina Aristei[2]

Alissa Melinger[3]

Rasha Abdel Rahman[1]

[1]Humboldt-Universität zu Berlin, Germany

[2]University of Luxembourg, Luxembourg

[3]University of Dundee, Scotland, UK

Running Head: SEMANTIC SIMILARITY INCREASES COMPETITION

Address for correspondence:

Rasha Abdel Rahman

Humboldt-Universität zu Berlin

Rudower Chaussee 18

12489 Berlin

Germany

Phone: +49-30-2093-9413

Email: rasha.abdel.rahman@hu-berlin.de

Abstract

Heterogeneous effects of semantic distance in language production have sparked a debate on the central assumption of many language production models, namely that lexical selection is a competitive process. In the present ERP study we manipulated semantic distance in the picture word interference (PWI) paradigm systematically within taxonomic hierarchies. Target - distractor pairs were either closely related members of the same basic level category, hence sharing many semantic features (e.g., orangutan and gorilla), or distantly related members of the same superordinate category, sharing fewer features (e.g., orangutan and horse). Across related conditions, broad category membership (e.g., animals) was kept constant. Naming times reflected a systematic increase of semantic interference as semantic distance decreased. Early and later ERP modulations related to the semantic distance manipulation were observed at posterior regions starting at 234 ms and with an additional fronto-central cluster starting at 346 ms.. Early effects are interpreted as indexing lexical selection while the late effects may reflect an N400-like component. Taking the behavioral and ERP modulations together, these results are in line with models of lexical selection that include an early competitive lexical selection process.

KEYWORDS: Language production; Semantic distance; Semantic interference; Picture word interference; Electrophysiology

Introduction

Inhibitory semantic context effects in picture naming tasks have long been taken as evidence for the competitive nature of lexical selection in language production. For instance, naming a picture (e.g., dog) is delayed in the presence of a semantically related distractor word (e.g., cat) relative to an unrelated word (e.g., pen) (e.g., Damian & Bowers, 2003; Glaser & Dungelhoff, 1984; Glaser & Glaser, 1989; Hantsch, Jescheniak, & Schriefers, 2005; Schriefers, Meyer, & Levelt, 1990). According to lexical competition models (cf. Bloem & La Heij, 2003; Bloem, van den Boogaard, & La Heij, 2004; La Heij, Kuipers, & Starreveld, 2006; Levelt, 1992; Levelt, Roelofs, & Meyer, 1999; Roelofs, 2018), target picture processing includes the co-activation of semantically related concepts and their corresponding lexical representations, which compete with the target for selection. Related distractor words contribute to this lexical competition by further enhancing the activation levels of non-target lexical representations, resulting in delayed selection relative to unrelated words (e.g.; Damian & Bowers, 2009; Dell'Acqua et al., 2010; La Heij, Heikoop, Akerboom, & Bloem, 2003; Melinger & Abdel Rahman, 2013; Roelofs, 1992; Schriefers et al., 1990; Vieth, McMahon, & de Zubicaray, 2014a).

One core assumption of lexical competition models is that competitive activation depends on the degree of semantic similarity (or distance) between representations. This factor determines the amount of activation spread within conceptual and between conceptual and lexical stages, where strongly related co-activated representations should compete more than weakly related representations due to high feature overlap (Dell, 1986; Roelofs, 1992; Vigliocco, Vinson, Damian, & Levelt, 2002; Vigliocco, Vinson, Lewis, & Garrett, 2004). Indeed, Vigliocco and colleagues (2004) reported modulated interference as a function of semantic distance in the PWI paradigm, with close distractors inducing stronger interference than more distantly related words. While similar semantic distance effects have been reported in subsequent studies using different naming paradigms (Aristei & Abdel Rahman, 2013; Navarrete, Del Prato, & Mahon, 2012, Experiment 3a and b; Vieth et al., 2014a, Experiment 2), others reported either no effects of semantic distance (Hutson & Damian, 2014; Navarrete et al., 2012, Experiment 2; Vieth et al., 2014a, Experiment 1), or faster naming in the context of close relative to distantly related distractors (Mahon, Costa, Peterson, Vargas, & Caramazza, 2007). These latter results challenge competitive models of lexical selection.

As an alternative to lexical competition models, Mahon and colleagues (2007) have formulated the response exclusion hypothesis to explain semantic context effects in the PWI task, including the facilitatory semantic distance effects they reported. Here, semantic relations may induce graded facilitatory, instead of inhibitory, effects. Specifically, according to this model, all semantic contexts induce facilitation due to semantic priming, with close semantic relations inducing more facilitation than distant semantic contexts due to higher semantic feature overlap with the target. Interference is assumed to originate at the post-lexical stage of the articulatory output buffer, to which word distractors have privileged access. The output buffer constitutes a bottleneck that can be engaged with only one representation at a time; therefore the distractor must be removed before the target word can be produced (see also Dhooge & Hartsuiker, 2012). The speed of exclusion depends on the response relevance of the distractor as a binary factor: unrelated words are quickly dismissed because they are not eligible as response candidates. However, words sharing the broad semantic category with the target are potentially response relevant and therefore harder to reject. As a result, they are removed more slowly. Since the response relevance criterion is determined by the broad category membership, and is insensitive to graded differences in semantic distance (Mahon et al., 2007), close and distant distractors are equally response relevant; thus, exclusion times should be identical. Since close distractors induce stronger priming than distant distractors but take equal time to clear from the response buffer, they should be named faster than distant distractors, as was observed in Mahon and colleagues' experiments (2007).

Irrespective of these theoretical aspects, one factor that may contribute to the inconsistency of semantic distance effects across studies is that diverse measures of semantic distance have been employed. For instance, two stimuli may be classified as closely related based on isolated shared features (e.g., the color: strawberry and lobster), even though they do not share the same semantic category and associated features (e.g., Mahon et al., 2007; Hutson & Damian, 2014, Experiment 1; Vieth et al., 2014a, Experiment 2; Vigliocco et al., 2002). The same stimuli may be classified as distantly related based on semantic similarity ratings that tend to underestimate distinctive features (Cree & McRae, 2003; Hutson & Damian, 2014, Experiment 2; Mahon et al., 2007; Vieth et al., 2014a, Experiment 1). Because shared and distinctive features may induce opposite effects in naming tasks (Vieth, McMahon, & de Zubicaray, 2014b; Rabovsky, Schad, & Abdel Rahman, 2016), measures that favor one over the other may lead to stimulus sets that induce effects of different polarity. Therefore, the types of semantic relation within and across categories may vary greatly between items within single studies as well as between different studies, and the specific measures used to define semantic relations may determine the polarity of the semantic distance effects.

In the present study, to create a more consistent stimulus set, we manipulated semantic distance systematically within taxonomic hierarchies (cf. Aristei & Abdel Rahman, 2013; Navarrete et al., 2012; Rose & Abdel Rahman, 2016), thereby avoiding the aforementioned problems associated with heterogeneous materials. While superordinate category membership was held constant in the related conditions, the number of shared semantic features was manipulated as a function of the taxonomic relation between target and distractor. Specifically, in the distant condition, target and distractor are members of the same superordinate category but stem from different basic level categories, sharing few semantic features. In contrast, in the close condition, target and distractor are drawn from a common basic level category, sharing many features. For example, the orangutan shares only a limited number of features with other animals (e.g., horse), but many features with other members of the ape category (e.g., gorilla).

According to traditional competitive models of lexical selection (e.g., Levelt et al., 1999; see also Vigliocco et al., 2004), graded effects should be observed with stronger semantic interference for closely related relative to distantly related distractors, and fastest naming times for unrelated distractors. In contrast, according to the response exclusion hypothesis, close and distant distractors are members of the same superordinate category and are therefore equally response relevant; however, at the lexical level, close distractors should induce stronger semantic priming. Therefore, naming times should be faster in the close relative to the distant condition, and due to reduced priming, semantic interference effects are likely to be larger in the distant than the close condition, relative to the unrelated condition.

We used event-related potentials (ERPs) to gain further insight into the time course of semantic distance effects during naming. Competitive models assume that semantic interference should arise during early stages of word production (lexical selection), whereas the response exclusion hypothesis suggests that semantic interference should arise much later, close to articulation. Accordingly, lexical competition models predict early ERP modulations during lexical-semantic processing stages around 150 and 250 ms (Indefrey, 2011), while the response exclusion hypothesis predicts no such early modulations.

Empirically, semantic context effects in language production have been associated with ERP effects at anterior and posterior sites, in line with neuroimaging, stimulation and patient studies reporting an involvement of (left)temporal and frontal regions (e.g., de Zubicaray, Wilson, McMahon, & Muthiah, 2001; Schnur, Schwartz, Brecher, & Hodgson, 2006; Schuhmann, Schiller, Goebel, & Sack, 2012; Wirth et al., 2011).

ERP studies investigating naming in a variety of semantic context paradigms have reported early context effects starting between 150 and 250 ms at posterior sites (e.g., Aristei, Melinger, & Abdel Rahman, 2011; Costa, Strijkers, Martin, & Thierry, 2009; Dell'Acqua et al., 2010; Maess, Friederici, Damian, Meyer, & Levelt, 2002; see also, Strijkers, Costa, & Thierry, 2010; see Indefrey & Levelt, 2004). Specifically, negative going ERPs corresponding to semantic effects have been reported in the cyclic blocking paradigm (homogeneous minus heterogeneous), associated with lexical-semantic processing (e.g., Aristei et al., 2011), likewise, a positive component around 200 ms has been related to lexical selection in the continuous naming task (later repetitions more positive compared to earlier repetitions; Costa et al., 2009; see also Rose & Abdel Rahman, 2017 for a similar positivity). Furthermore, examining the distractor frequency effect, Riés, Fraser, McMahon, and de Zubicaray (2015) observed early (100-300 ms) ERP modulations at frontal and temporal scalp regions (high frequency more negative than low frequency), which they attribute to competition during lexical selection. Additionally, left frontal ERP modulations (more negative amplitudes for semantic relations/blocked conditions compared to unrelated/heterogeneous conditions) have been taken as evidence for enhanced cognitive control mechanism during the resolution of lexical competition (e.g., Aristei, et al., 2011).

In the PWI task, a relatively early positivity associated with related compared to unrelated masked distractors has been interpreted as an early onset of the N400 component and hence to reflect semantic priming, rather than lexical selection (Blackford, Holcomb, Grainger, & Kuperberg, 2012; Janssen, Hernandez-Cabrera, van der Meij, & Barber, 2015; see also Roelofs, Piai, Garrido Rodriguez, & Chwilla, 2016 for crosslingual N400 effects in the PWI task). Indeed, several PWI studies have reported modulations of the N400 family with a fronto-central maximum between 300-500ms and a more positive amplitude in the related relative to the unrelated condition (Blackford, et al., 2012; Greenham, Stelmack, & Campbell, 2000). Since both lexical competition models and response exclusion models of semantic interference predict early semantic facilitation, these early N400-like modulations do not arbitrate between views. Instead, both approaches predict a second, additional, effect. Early locus models predict another early modulation that indexes resolution of lexical competition (cf. Abdel Rahman & Melinger, 2009) while late locus models predict a late modulation close to articulation. Critically, then, only early locus models predict modulations linked to semantic contexts that precede N400-like modulations.

Consistent with the former prediction, Piai and colleagues (Piai, Roelofs, Jensen, Schoffelen, & Bonnefond, 2014) have reported MEG evidence for a temporal overlap between priming and competition in the PWI paradigm. In line with the idea that conceptual and lexical processes largely overlap in time, they found interference to correspond to reduced activity between 350 and 650ms at left-temporal regions, most likely reflecting semantic-lexical priming. Simultaneously, activity at left prefrontal regions increased for related vs. unrelated distractors, analogous to the behavioral interference effect. Piai et al. suggested that this region was involved in the resolution of lexical competition. Hence, distinct ERP modulations reflecting lexical competition resolution and semantic priming may co-exist with each being reflected in a different component, which contributes to the overall semantic context effects, (see Abdel Rahman & Melinger, 2009 for a similar argument).

To summarize, according to lexical competition models, reaction times should gradually increase from unrelated to distantly related to closely related words, whereas the opposite pattern should be found according to the response exclusion account. In ERPs, lexical competition models predict an early modulation around the time of lexical-semantic processing which should be followed by an N400-like modulation. The response exclusion account predicts that the N400 priming effect should be the only early effect linked to semantic context, with semantic interference effects emerging closer to articulation. The study was approved by the local ethics committee.

Methods

Participants. 24 right-handed subjects, aged 19 – 30 years (M = 23.4, SD = 3.7) with normal or corrected-to-normal visual acuity and normal color vision participated for monetary compensation or for course credits. All participants were native German speakers and gave informed consent before experiment.

Materials. Stimuli were 125 color photographs of common objects scaled to 3.5 cm x 3.5 cm. The objects stemmed from five different superordinate categories (animals, clothes, tools, groceries, furniture), each subdivided into five basic level categories (e.g., animals: birds, fish, etc.; groceries: fruit, beverages, etc. see Appendix). The pictures were relatively easy to identify, and were typically not confused with other category members. The materials were selected to avoid strong visual similarities between members of small categories. We did so 1) by selecting pictures from different perspectives and avoiding unnecessary similarities and by 2) by choosing close category members that are visually different (e.g., “eagle” vs. “owl”); please see supplementary material for the complete list).

Each target object (e.g., eagle) was presented in three distractor conditions with a semantically close (owl), distant (gorilla) and unrelated word (bed). In the close condition target and distractor were members of a basic level category (e.g., monkeys) sharing many semantic features; in the distant condition they were members of a superordinate category, sharing few features. All distractor words were part of the response set. The unrelated condition was constructed by rearranging related target-distractor pairs. The words were presented in red color and super-imposed on the object pictures. Distractors were positioned so as not to obscure the image; hence, distractor placement differed between pictures. To avoid unwanted confounds, the distractor position for each picture remained constant across conditions.

Design and Procedure. Prior to the experiment, each participant was familiarized with the objects and their subordinate names. The objects' photographs were presented in random order on a monitor and participants were asked to name each picture with its specific name at the subordinate level. If necessary, they were provided with the right name by the experimenter. After this procedure and while the EEG recording was prepared, participants were given sheets of paper with all pictures and their names printed below. Afterwards the PWI task started and participants were instructed to name the pictures on the monitor as fast and accurately as possible and to ignore the distractor words. Each trial began with a fixation cross displayed in the center of a light grey screen for 0.5 s. Then a picture-word pair was presented for 2 s (SOA=0), followed by a blank screen for 1 s. Naming latencies were measured with a voice key during the entire duration of picture presentation. After the naming response was registered, the picture disappeared and the next trial followed. Each picture-word pair was presented two times, resulting in 750 trials, and a duration of about 40 minutes. The presentation order of stimuli was randomized. After 40 trials, a pause screen was presented.

EEG Procedure. The continuous EEG was recorded with 62 Ag/AgCl electrodes arranged according to the extended 10/20 system, referenced to an electrode at the left mastoid. The sampling rate was 500 Hz. To register eye movements and blinks, electrodes were placed near the left and right canthi of the eyes and above and beneath the left eye. Electrode impedance was kept below 5 kOhm. Offline EEG was re-referenced using the average reference, and low-pass filtered (high cutoff = 30 Hz, 24 dB/oct). Eye movements and blink artifacts were removed employing the Multiple Source Eye Correction (MSEC) method implemented in BESA software (Berg & Scherg, 1994). In order to minimize possible distortion of the signal with cognitive sources, characteristic scalp topographies for blinks and eye movements were sampled for each participant individually during calibration trials (controlled eye movements in response to single tokens on the screen, e.g. a depicted left arrow to induce left eye movements; see Dimigen et al., 2011 for details and discussion). The resulting spatio-temporal patterns reflecting the artifacts were then subtracted from the raw EEG. Afterwards, remaining artifacts were eliminated with an automatic artifact rejection procedure, excluding segments with potentials exceeding 50 µV voltage steps per sampling point and a threshold of 200 µV. The EEG data were segmented in epochs of 2100 ms, starting 100 ms before the onset of the target. This 100 ms interval was used for baseline correction.

Because speaking can induce severe artifacts in the EEG (e.g., Brooker & Donald, 1980; Grozinger, Kornhuber, & Kriebel, 1975; Wohlert, 1993), we employed a recently developed method for correcting the EEG signal from articulation-related artifacts (Ouyang et al., 2016; see Porcaro, Medaglia, & Krott, 2015; Vos et al., 2010 for related approaches). Specifically, we used the residue iteration decomposition (RIDE) method that decomposes ERPs into separate component clusters with different trial-to-trial variabilities (e.g., stimulus-locked, response-locked and latency-variable component clusters). Articulation artifacts can be separated from the EEG signal based on their large amplitudes and highly variable trial-to-trial latencies. In the study by Ouyang et al. (2016) the EEG and movements of the inner and outer vocal tract were co-registered using Electromagnetic Articulography (EMA). The authors showed that initially high correlations between articulator activity and speech artifacts in the EEG with a typical frontal-positive posterior-negative distribution dropped to almost zero after artifact correction, demonstrating successful artifact removal. The residue iteration algorithm (RIDE) used here decomposes ERP data into component clusters, which can be used to separate and reject articulation artifacts (Ouyang et al., 2016). We separated our data into a stimulus-locked S-component (which is equivalent to the corrected ERP and analyzed; search interval 0 - 500 ms after stimulus onset) and an R-component containing the artifact (which is rejected from the data; search interval 500 – 2500 ms after stimulus onset), see Figure 1.

Insert Figure 1 here

Results

Behavioral results

Naming times gradually increase from unrelated to distantly related to closely related distractor conditions (see Figure 2). A repeated measures analysis of variance (ANOVA) of naming latencies with the factor semantic distance (close, distant, unrelated), and participants (F_1) and items (F_2) as random variables confirmed significant semantic distance effects, $F_1(2,46) = 21.9$, $p < .001$, $\eta_p^2 = .48$; $F_2(2,248) = 14.2$, $p < .001$, $\eta_p^2 = .1$. These were characterized by a linear trend, $F_1(1,23) = 38.7$, $p < 0.001$, $\eta_p^2 = .62$; $F_2(1,124) = 29.7$, $p < .001$, $\eta_p^2 = .19$, indicating that RTs increased linearly with decreasing semantic distance (close: $M = 943.53$, $SEM = 19.31$; distant: $M = 930.42$, $SEM = 20.49$; unrelated: $M = 916.50$, $SEM = 19.35$). Pairwise comparisons further confirmed this linear increase, showing significant differences between close and unrelated distractors ($t_1(23) = 6.2$, $p < .001$; $t_2(124) = 5.4$, $p < .001$), between distant and unrelated distractors ($t_1(23) = 3.5$, $p = .002$; $t_2(124) = 3.0$, $p = .003$), and between close and distant distractors ($t_1(23) = 3.2$, $p = .003$; $t_2(124) = 2.3$, $p = .023$).

A similar pattern was observed in the error rates, with increasing error rates as semantic distance decreases (close: *M* = 6.68, *SEM* = 1.0; distant: *M* = 5.46, *SEM* = 0.7; unrelated: *M* = 4.93, *SEM* = 0.9). Because of the categorical nature of the error data, errors were analyzed using mixed-effects logit models (cf. Jaeger, 2008) in R (version 3.4.3, R Development Core Team, 2016) using the packages LanguageR (Baayen, 2013) and lme4 (Bates, Maechler, Bolker, & Walker, 2014). All participant responses, with correct trials coded as 0 and error trials coded as 1, were entered into a model with a fully specified random effect structure (Barr, Levy, Scheepers, & Tily, 2013). The fixed factor in this model was Semantic Distance (Close, Distant, Unrelated). The coefficient estimate (β), standard error (SE), Wald z-value (z) and p-value were used to report the predictor parameters. The main effect of Semantic Distance was significant (β =-0.20178, SE = 0.05021, *z* = 4.02, p < .001). To assess the incremental effect of semantic distance, pairwise analyses were also conducted. These results mirror the linear nature of the semantic distance effect observed in the RT analysis: Close vs. Distant (MDiff = 1.22; β = -0.11959, SE = 0.05788, *z* = 2.066, p = .038); Distant vs. Unrelated (MDiff = 0.53; β = 0.13503, SE = 0.06868, *z* = 1.966, p = .049); Close vs. Unrelated (MDiff = 1.75; β = -0.25629, SE = 0.06316, *z* = 4.058, p < .001).

Insert Figure 2 here

Electrophysiological results

Only correct naming trials were included in the EEG analysis. Statistical analyses on error and artifact free data were performed with non-parametric cluster-based permutation tests (CBPT) as implemented in FieldTrip (Maris & Oostenveld, 2007¸ version 20161024; with the function ft_timelockstatistics; for a recent application on which the present approach is based on, see Frömer, Maier & Abdel Rahman, 2018) between 0 and 500 ms including each time point (2ms) and all 62 electrodes, with 1000 randomizations using the FieldTrip MATLAB toolbox (Oostenveld, Fries, Maris, & Schoffelen, 2011) to determine time windows and electrode clusters that diverge between conditions.

The results are presented in Figures 3 and 4. The tests revealed significant differences between the close and unrelated conditions (Figure 3, top row, $p = 0.0009$ for the positive cluster, and $p = 0.02$ for the negative cluster; for details, see below), and significant differences between the close and distant conditions (Figure 3, middle row, $p = 0.003$ for the early positive cluster and $p = 0.02$ for the later positive cluster). However, there were no differences between the distant and unrelated conditions (Figure 3, bottom row, *ps* >0.45). The effect of semantic distance can also be seen in Figure 4, with an augmented positivity in the close condition arising between 200 and 300ms and between 400 and 500.

Two clusters were identified to underlie the difference between the close and unrelated conditions. Starting at 234 ms and persisting until 480 ms, the closely related condition was associated with a stronger positive amplitude compared to the unrelated condition. This cluster emerges over posterior regions and then extends and broadens into central regions (Cluster 1; electrodes: Oz, O1/2, POz, PO3/4, PO7/8, Pz, P3/4, P5/6, P8, CPz, CP1/2, CP3/4, CP5/6, Cz, C1/2, C3/4, C5/6, FC1/2, FC3/4, FC6, F4; $p < .001$). Starting from 346 ms and persisting for 112 ms, a second cluster emerges at left fronto-central regions (Cluster 2; electrodes: TP7, TP9, T7, FT7, FC5, F3, F5, F7, F9, AFz, AF3, AF7, Fpz, Fp1/2) with more negative amplitudes in the close relative to the unrelated conditions($p = .02$).

The comparison between the close and distant condition revealed an early cluster, with a stronger positive amplitude associated with the close compared to the distant condition starting from 228 ms and extending until 292 ms at posterior electrode sites (cluster 1;

electrodes: Oz, O2, POz, PO3/4, PO8, PO10, Pz, P3/4, P6, P8, CPz, CP1/2, CP3/4, CP6, TP10, Cz, C2, C4, C6, T8; $p = .003$). After an interval of 54 ms in which no significant differences were observed, a second cluster, starting from 350 ms and extending for 124 ms, emerged with a centro-parietal distribution (cluster 2; electrodes: Oz, O1/2, POz, PO3/4, Pz, P3/4, P5/6, P8, CPz, CP1/2, CP3/4, CP6, Cz, C1/2, C3/4, C6, Fc1/2, FC4, FC6, Fz; $p = .02$). Unlike the close vs. unrelated comparison, no additional negative cluster at left fronto-central electrode sites was observed. The distant and unrelated conditions did not differ (cf. Figure 3).

Insert Figures 3 & 4 here

Discussion

In this study, we explored semantic distance effects on object naming in a PWI task with behavioral measures and ERPs. We manipulated semantic distance systematically within taxonomic hierarchies, keeping broad category membership constant. In contrast to recently reported failures to find graded semantic distance effects (Hutson & Damian, 2014; Vieth et al., 2014a), and contrary to the observation of longer naming times in the context of distant compared to close distractors (Mahon et al., 2007), we found a gradual increase of semantic interference with decreasing levels of semantic distance. The slowest naming responses were associated with closely related distractors, intermediate responses with distantly related distractors, and fastest responses with unrelated words. This pattern is in line with some previous reports across different naming paradigms (Vigliocco et al., 2004; Aristei & Abdel Rahman, 2013 in the PWI task; see also Navarrete et al., 2012 Experiment 3; Vigliocco et al., 2002 in blocked cyclic naming, and Rose & Abdel Rahman, 2017 in the continuous naming task).

This finding confirms predictions derived from traditional lexical competition models, assuming that the impact of semantically related words on lexical competition is augmented by the strength of activation spread between concepts as a function of their semantic feature overlap (Dell, 1986; Roelofs, 1992; Vigliocco et al., 2002; Vigliocco et al., 2004). It cannot be explained by the non-competitive response exclusion account (Mahon et al., 2007), which predicts the opposite pattern of interference in naming times, with slower naming in the context of distant compared to close distractors.

It also contrasts with an alternative attempt to account for the effects of Mahon and colleagues within a competitive framework. Abdel Rahman and Melinger (2009a, 2009b) argued in their model that the polarity of semantic context effects depends on the outcome of a trade-off between conceptual facilitation due to semantic priming and interference due to lexical competition. According to this swinging lexical network (SLN) account, the dominance of interference is determined by the activation of a lexical cohort that consists of an assembly of simultaneously co-activated semantic-lexical representations, and crucially the size of semantic interference is directly related to the size of the active lexical cohort. Thus, not only the activation strength of (single) competitors, but also the number of active competitors is assumed to affect lexical selection times and semantic interference. Assuming that closely related target-distractor pairs (e.g., owl, eagle) co-activate a category consisting of fewer members (birds) than categories co-activated by more distant target-distractor pairs (e.g., animals: owl, tiger), smaller interference in the close condition could be expected.

However, the present findings show that the *strength* of lexical co-activation, even of a relatively small cohort, is a crucial factor. If increasing cohort size goes along with a decrease in the strength of mutual co-activation – as is the case for loosely related members of broad categories – the effect is weaker than the competition induced by a cohort of highly active competitors that co-activate each other, even if this cohort is of smaller size. Thus, it is the combined net effect of cohort size and activation strength, rather than either of these effects alone, that can explain the slower naming associated with close compared to distant distractors observed here. Specifically, closely related items share many specific features and their activation spread converges on a small assembly of strongly interrelated and co-activated lexical representations, thereby intensifying lexical competition. In contrast, distantly related items share more global features and induce a wide but relatively unspecific activation spread between many loosely connected concepts - without strong converging activation patterns. Consistent with this view, there is a growing body of evidence demonstrating both the independent importance of cohort size and activation strength (e.g., Rose & Abdel Rahman, 2016; Rabovsky, et al., 2016) as well as the interaction between them (Fieder, Wartenburger & Abdel Rahman, submitted). Thus, the present finding adds to this growing literature by illuminating the interaction between cohort size and activation strength, thereby clarifying the swinging lexical network account.

While the results can be integrated into the SLN account, it seems harder to reconcile them with the response-exclusion account proposed by Mahon and colleagues (2007). Specifically, a fundamental claim of the original response-exclusion proposal is that the exclusion mechanism is tuned to assess response relevance and semantic distance or semantic feature overlap is orthogonal to response relevance. It is this fundamental claim that allows the model to account for observations of semantic facilitation when traditional competition models predict interference. However, the present results would require the response exclusion account to accept that semantic feature overlap contributes to response relevance. By doing so, the time needed to exclude a distractor could be modulated by the closeness of the semantic relationship between target and distractor. However, it is unclear whether this revised conceptualization of the exclusion mechanism would still have the explanatory breath of the original proposal. Furthermore, to directly explain the strong inhibitory effects of semantic similarity found here, proponents would need additional assumptions on which of the opposing effects, lexical-semantic facilitation or response exclusion, would be stronger at any given time.

The graded RT effects found in the present study might be a consequence of the specific distance manipulation used. Most studies that failed to report graded semantic distance effects selected their stimuli according to feature generation norms (Hutson & Damian, 2014, Experiment 1; Mahon et al., 2007; Vieth et al., 2014a, Experiment 2; Vigliocco et al., 2002) or semantic similarity ratings (Cree & McRae, 2003; Hutson & Damian, 2014, Experiment 2; Mahon et al., 2007; Vieth et al., 2014a, Experiment 1). By using these measures, stimuli might be classified as semantically close even though they only share specific features (e.g., the color or shape) and stem from different semantic categories. Such inconsistencies can be avoided by using a taxonomic operationalization of semantic distance; by using superordinate and basic level categories, the membership to a common broad category is held constant between conditions.

In ERPs (Figure 3), when comparing the closely related condition to the unrelated condition, we identified an early posterior cluster with a positive amplitude modulation (close minus unrelated), starting at 234 ms. A topographically similar early modulation was also observed when comparing the close vs. distant conditions. This was followed by a second positive cluster with a centro-parietal distribution (distant vs. unrelated). Finally, in addition to these positive modulations, we also observed an additional later negative cluster of left central and frontal electrodes in the close vs. unrelated comparison, which was absent in the close vs. distant comparison.

The onset of the early posterior effects, around 236 ms, is in line with other EEG / MEG studies manipulating semantic contexts in different naming paradigms (e.g., Aristei et al., 2011; Costa et al., 2009; Maess et al., 2002; Dell'Acqua et al., 2010; see Indefrey, 2011 for a metaanalysis). A very similar posterior positivity at about 200 ms has been reported in other semantic context paradigms and taken to reflect lexical selection (e.g., Costa et al., 2009; Strijkers et al., 2010). Indeed, Rose & Abdel Rahman (2017) used the same semantic relations and materials as employed here in a continuous naming task and, comparing the close vs. unrelated conditions, reported a relative early posterior positivity very similar to the one observed here. Thus, in line with previous interpretations and predictions derived from lexical competition models, we conclude that the relative posterior positivity found here also reflects competitive lexical selection, with stronger competition in the closely related condition than is observed in either the distant or unrelated conditions.

The later positive modulation observed in the close vs. distant comparison, Cluster 2, has many of the hallmarks of the N400 family: The modulations emerge at 350ms over a cluster with a typical centro-parietal distribution. The N400 is associated with semantic processing and is commonly reported in Stroop and PWI experiments (Liotti et al, 2000, Piai et al, 2012, Shitova et al, 2016, Wong et al, 2017). Given the closer semantic relationship implemented in the close compared to the distant conditions, it was predicted that we would observe an N400 effect. However, an N400 was also predicted for the close vs. unrelated condition, but in that comparison it is difficult to isolate a later effect because the early modulations are longer lasting.

The shorter duration of the early ERP modulations in the close vs. distant comparison is in line with other reports and theoretical predictions (Indefrey, 2011). We can only speculate about the reasons for the longer duration in the close vs. unrelated comparison. However, it is highly unlikely that the entire extended modulation observed in the close vs.

unrelated comparison, which extends for over 200ms, reflects only lexical selection, which have been suggested to have a typical duration of approximately 75ms (Indefrey, 2011). Therefore, we suggest that, like in the close vs. distant condition, the positive modulations observed in the close vs. unrelated condition actually reflect (at least) two temporally overlapping cognitive processes: the early modulation reflecting competitive lexical selection and a later modulation that reflects semantic effects of the N400 family (see also Piai et al., 2014).

The N400 modulation may specifically reflect the larger number of semantic features and neighbors shared between picture and distractor in the closely related condition compared to the unrelated condition, where there are minimal links between picture and distractor. In contrast, in the distant condition, the semantic relationships established between the picture name and distractor word are weaker, resulting in weaker semantic processing than in the closely related condition.

A third possibility is that the early posterior positivity observed in the close vs. unrelated comparison may not reflect mechanisms of lexical selection at all, but rather fast feed forward processes that stabilize at later stages in the form of an N400 (Blackford et al., 2012; Janssen et al., 2015). Evidence against such an interpretation of our early positivity comes from the activation pattern observed in the close vs. distant conditions. There, as discussed above, we see the emergence of two distinct ERP modulations, which mirror the effects proposed for the close vs. unrelated conditions. It would be unlikely to observe modulations reflecting lexical selection in the close vs. distant comparison but then observe similar modulations in the close vs. unrelated comparison deserving of a differing interpretation.

One might ask why semantic effects should appear after lexical selection. We argue that the N400 is not the earliest brain activity related to semantic processing, and that at early points in time conceptual and lexical processes are strongly overlapping both temporally and spatially (e.g., Abdel Rahman & Melinger, 2009 a, b; Piai et al., 2015). Indeed, many studies on word processing suggest that access to semantic information starts earlier than the average latency or peak of the N400 component (e.g., Rabovsky et al., 2012). Indeed, Thorpe, Fize, and Marlot (1996) demonstrated that basic semantic information can be available within 150ms of picture presentation. Furthermore, the temporal regions where lexical selection is assumed to take place are also assumed to be the regions where semantic information and object concepts are processed (Visser, Jefferies, Embleton, & Ralph., 2012). Thus, conceptual and lexical processes largely overlap, with long-lasting conceptual processes starting before and continuing during and even after lexical selection, producing an overlap in ERPs (see Abdel Rahman & Sommer, 2003; Abdel Rahman, van Turennout & Levelt, 2003 for evidence of parallel conceptual and phonological activation; Indefrey, 2011).

Finally, in the comparison between close and unrelated conditions, we observed a negative amplitude modulation at left fronto-central sites, starting at 346 ms. This activation may reflect enhanced cognitive control mechanisms during the resolution of lexical competition (cf. Aristei, et al, 2011; de Zubicaray & Mcmahon, 2009; Schnur et al, 2009). However, this conclusion must be very tentative because many of the studies that have demonstrated activation in these regions used fMRI, which has poorer temporal resolution but much finer spatial resolution, allowing them to pinpoint specific brain regions. EEG, in contrast, has good temporal resolution but weak spatial resolution. Therefore, it is difficult to interpret EEG components on the basis of imaging research. For now, we simply point out that the negative modulation (close minus unrelated) over this left-lateralized cluster is unique to the close vs. unrelated condition; no sign of a similar left-lateralized anterior effect is observed in the close vs. distant comparison.

To summarize, we interpret the early relative posterior positivity as reflecting increased lexical competition in the close condition compared to either distant or unrelated conditions. The later more central modulations are interpreted as N400 type effects related to the differences in the number of semantic features that are co-activated. We assume that an N400 is also present in the close vs. unrelated comparison, although the individual components are harder to identify do to overlapping modulations. We speculate that the left-lateralized anterior negative modulations may reflect enhanced cognitive control mechanisms during the resolution of lexical competition in the close vs unrelated condition that may be particularly strong when distractor words are presented.

Theoretically, competition models of lexical selection assume that early effects resulting from lexical competition should emerge in the time window of around 200-250ms (Indefry & Levelt, 2004; Indefrey, 2011). In contrast, non-competitive models of lexical selection such as the Response Exclusion Hypothesis (Mahon et al, 2007) predict that semantic context effects should only emerge at later time windows; no early effect are predicted. Both theories predict an N400-like modulation. Our early posterior modulations associated with the semantically close condition compared to the semantically distant and semantically unrelated conditions are therefore consistent with the predictions of competition models but more difficult to interpret within the context of a non-competitive model.

In contrast to RTs, we did not observe graded ERP modulations. Specifically, even though distantly related distractors induced behavioral interference, no corresponding ERP modulations were found when comparing the distantly related distractor condition to the unrelated condition. We can only speculate about possible reasons. ERP differences between close and unrelated distractors were already relatively small and may have been too small to result in measurable ERP effects in the distant condition. In general, the available EEG studies seem to suggest that ERP modulations in the PWI paradigm are less pronounced than in other semantic context paradigms (cf. Hirschfeld, Jansma, Bölte, & Zwitserlood, 2008; Piai et al., 2012), such as the cyclic and continuous naming paradigms (e.g., Aristei et al., 2011; Costa, et al., 2009), and other measures and techniques may be more suitable to detect distractor-mediated brain responses (e.g., Piai et al., 2012; Piai et al., 2014).

Taken together, the present findings are in contrast to the response exclusion account predicting reversed behavioral effects with faster naming times for close relative to distant distractors and no early ERP modulations preceding the N400. The findings of gradually increasing behavioral interference associated with decreasing levels of semantic distance and the early onsets of ERP modulations starting at about 230 ms – and that can be distinguished from later modulations of the N400 family- support language production models that incorporate competitive lexical selection. They furthermore suggest that the impact of semantic activation of competing lexical representations is strongly influenced by semantic feature overlap that can be viewed as a major determinant for semantic interference.

Acknowledgments

This research was supported by a grant (AB 277/ 4) from the German Research Council to Rasha Abdel Rahman. We thank Anna Eiserbeck, Johannes Rost and Alina Karafiat for help with data acquisition and analysis.

References

Abdel Rahman, R., & Melinger, A. (2007). When bees hamper the production of honey: Lexical interference from associates in speech production. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 33*(3), 604-614.

Abdel Rahman, R., & Melinger, A. (2009a). Dismissing lexical competition does not make speaking any easier: A rejoinder to Mahon and Caramazza (2009). *Language and Cognitive Processes, 24*(5), 749-760.

Abdel Rahman, R., & Melinger, A. (2009b). Semantic context effects in language production: A swinging lexical network proposal and a review. *Language and Cognitive Processes, 24*(5), 713-734.

Abdel Rahman, R., Van Turennout, M., & Levelt, W. J. (2003). Phonological encoding is not contingent on semantic feature retrieval: an electrophysiological study on object naming. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29*(5), 850-860.

Abdel Rahman, R., & Sommer, W. (2003). Does phonological encoding in speech production always follow the retrieval of semantic knowledge?: Electrophysiological evidence for parallel processing. *Cognitive Brain Research, 16*(3), 372-382.

Aristei, S., & Abdel Rahman, R. (2013). Semantic interference in language production is due to graded similarity, not response relevance. *Acta Psychologica, 144*(3), 571-582.

Aristei, S., Melinger, A., & Abdel Rahman, R. (2011). Electrophysiological chronometry of semantic context effects in language production. *J Cogn Neurosci, 23*(7), 1567-1586.

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. Journal of Memory and Language, 68(3), 255–278. https://doi.org/10.1016/j.jml.2012.11.001

Baayen, R. H. (2013). languageR: Data sets and functions with "Analyzing Linguistic Data: A practical introduction to statistics". (R package on CRAN).

Bates, D., Maechler, M., Bolker, B., Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software, 67*(1), 1-48, doi:10.18637/jss.v067.i01.

Berg, P., & Scherg, M. (1994). A multiple source approach to the correction of eye artifacts. *Electroencephalography and clinical neurophysiology*, *90*(3), 229-241.

Blackford, T., Holcomb, P. J., Grainger, J., & Kuperberg, G. R. (2012). A funny thing happened on the way to articulation: N400 attenuation despite behavioral interference in picture naming. *Cognition, 123*(1), 84-99.

Bloem, I., & La Heij, W. (2003). Semantic facilitation and semantic interference in word translation: Implications for models of lexical access in language production. *Journal of Memory and Language*, *48*(3), 468-488.

Bloem, I., van den Boogaard, S., & La Heij, W. (2004). Semantic facilitation and semantic interference in language production: Further evidence for the conceptual selection model of lexical access. *Journal of Memory and Language, 51*(2), 307-323.

Brooker, B. H., & Donald, M. W. (1980). Contribution of the speech musculature to apparent human EEG asymmetries prior to vocalization. *Brain and Language*, *9*(2), 226-245.

Costa, A., Strijkers, K., Martin, C., & Thierry, G. (2009). The time course of word retrieval revealed by event-related brain potentials during overt speech. *Proceedings of the National Academy of Sciences of the United States of America, 106*(50), 21442-21446.

Cree, G. S., & McRae, K. (2003). Analyzing the factors underlying the structure and computation of the meaning of chipmunk, cherry, chisel, cheese, and cello (and many other such concrete nouns). *Journal of Experimental Psychology-General*, *132*(2), 163-201.

Damian, M. F., & Bowers, J. S. (2003). Locus of semantic interference in picture-word interference tasks. *Psychonomic Bulletin & Review, 10*(1), 111-117.

Damian, M. F., & Bowers, J. S. (2009). Assessing the role of orthography in speech perception and production: Evidence from picture-word interference tasks. *European Journal of Cognitive Psychology, 21*(4), 581-598.

de Zubicaray, G. I., Wilson, S. J., McMahon, K. L., & Muthiah, S. (2001). The semantic interference effect in the picture-word paradigm: An event-related fMRI study employing overt responses. *Human Brain Mapping, 14*(4), 218-227.

de Zubicaray, G. I., & McMahon, K. L. (2009). Auditory context effects in picture naming investigated with event-related fMRI. *Cognitive, Affective, & Behavioral Neuroscience*, *9*(3), 260-269.

Dell'Acqua, R., Sessa, P., Peressotti, F., Mulatti, C., Navarrete, E., & Grainger, J. (2010). ERP evidence for ultra-fast semantic processing in the picture-word interference paradigm. *Frontiers in Psychology*, *1*.

Dell, G. S. (1986). A Spreading-Activation Theory of Retrieval in Sentence Production. *Psychological Review, 93*(3), 283-321.

Dhooge, E., & Hartsuiker, R. J. (2012). Lexical selection and verbal self-monitoring: Effects of lexicality, context, and time pressure in picture-word interference. *Journal of Memory and Language*, *66*(1), 163-176.

Dimigen, O., Sommer, W., Hohlfeld, A., Jacobs, A. M., & Kliegl, R. (2011). Coregistration of eye movements and EEG in natural reading: analyses and review. *Journal of Experimental Psychology: General*, *140*(4), 552.

Frömer R, Maier M, Abdel Rahman R (2018) Group-Level EEG-Processing Pipeline for Flexible Single Trial-Based Analyses Including Linear Mixed Models. *Front Neurosci 12*.

Glaser, W. R., & Dungelhoff, F. J. (1984). The Time Course of Picture Word Interference. *Journal of Experimental Psychology: Human Perception and Performance, 10*(5), 640-654.

Glaser, W. R., & Glaser, M. O. (1989). Context Effects in Stroop-Like Word and Picture-Processing. *Journal of Experimental Psychology: General, 118*(1), 13-42.

Greenham, S. L., Stelmack, R. M., & Campbell, K. B. (2000). Effects of attention and semantic relation on event-related potentials in a picture-word naming task. *Biological Psychology, 55*(2), 79-104.

Grözinger, B., Kornhuber, H. H., & Kriebel, J. (1975). Methodological problems in the investigation of cerebral potentials preceding speech: determining the onset and suppressing artefacts caused by speech. *Neuropsychologia*, *13*(3), 263-270.

Hantsch, A., Jescheniak, J. D., & Schriefers, H. (2005). Semantic competition between hierarchically related words during speech planning. *Memory & Cognition, 33*(6), 984-1000.

Hirschfeld, G., Jansma, B., Bölte, J., & Zwitserlood, P. (2008). Interference and facilitation in overt speech production investigated with event-related potentials. *Neuroreport, 19*(12), 1227-1230.

Hutson, J., & Damian, M. F. (2014). Semantic gradients in picture-word interference tasks: is the size of interference effects affected by the degree of semantic overlap? *Frontiers in Psychology, 5*.

Indefrey, P. (2011). The spatial and temporal signatures of word production components: a critical update. *Front Psychol, 2*, 255.

Indefrey, P., & Levelt, W. J. M. (2004). The spatial and temporal signatures of word production components. *Cognition, 92*(1-2), 101-144.

Jaeger, T. F. (2008). Categorical data analysis: Away from ANOVAs (transformation or not) and towards logit mixed models. *Journal of memory and language, 59*(4), 434-446.

Janssen, N., Hernandez-Cabrera, J. A., van der Meij, M., & Barber, H. A. (2015). Tracking the Time Course of Competition During Word Production: Evidence for a Post-Retrieval Mechanism of Conflict Resolution. *Cereb Cortex, 25*(9), 2960-2969.

La Heij, W., Heikoop, K. W., Akerboom, S., & Bloem, I. (2003). Picture naming in picture context: Semantic interference or semantic facilitation?. *Psychology Science, 45*(1), 49-62.

La Heij, W., Kuipers, J. R., & Starreveld, P. A. (2006). In defense of the lexical-competition account of picture-word interference: A comment on Finkbeiner and Caramazza (2006). *Cortex*, *42*(7), 1028-1031.

Levelt, W.J. (1992). Accessing words in speech production: stages, processes and representations. *Cognition, 42*(1-3), 1-22.

Levelt, W.J., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. *The Behavioral and Brain Sciences, 22*(1), 1-38; discussion 38-75.

Liotti, M., Woldorff, M. G., Perez, R., & Mayberg, H. S. (2000). An ERP study of the temporal course of the Stroop color-word interference effect. *Neuropsychologia*, *38*(5), 701-711.

Maess, B., Friederici, A. D., Damian, M., Meyer, A. S., & Levelt, W. J. M. (2002). Semantic category interference in overt picture naming: Sharpening current density localization by PCA. *Journal of Cognitive Neuroscience*, *14*(3), 455-462.

Mahon, B. Z., Costa, A., Peterson, R., Vargas, K. A., & Caramazza, A. (2007). Lexical selection is not by competition: A reinterpretation of semantic interference and facilitation effects in the picture-word interference paradigm. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 33*(3), 503-535.

Maris, E., & Oostenveld, R. (2007). Nonparametric statistical testing of EEG-and MEG-data. *Journal of neuroscience methods*, *164*(1), 177-190.

Melinger, A., & Abdel Rahman, R. (2013). Lexical Selection Is Competitive: Evidence From Indirectly Activated Semantic Associates During Picture Naming. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *39*(2), 348-364.

Navarrete, E., Del Prato, P., & Mahon, B. Z. (2012). Factors determining semantic facilitation and interference in the cyclic naming paradigm. *Frontiers in Psychology, 3*.

Oostenveld, R., Fries, P., Maris, E., & Schoffelen, J. M. (2011). FieldTrip: open source software for advanced analysis of MEG, EEG, and invasive electrophysiological data. *Computational intelligence and neuroscience, 2011*, 1.

Ouyang, G., Sommer, W., Zhou, C., Aristei, S., Pinkpank, T., & Rahman, R. A. (2016). Articulation artifacts during overt language production in event-related brain potentials: Description and correction. *Brain topography*, *29*(6), 791-813.

Piai, V., Roelofs, A., Jensen, O., Schoffelen, J. M., & Bonnefond, M. (2014). Distinct Patterns of Brain Activity Characterise Lexical Activation and Competition in Spoken Word Production. *Plos One*, *9*(2).

Piai, V., Roelofs, A., & van der Meij, R. (2012). Event-related potentials and oscillatory brain responses associated with semantic and Stroop-like interference effects in overt naming. *Brain Research*, *1450*, 87-101.

Piai, V., Roelofs, A., Rommers, J., & Maris, E. (2015). Beta oscillations reflect memory and motor aspects of spoken word production. *Human brain mapping*, *36*(7), 2767-2780.

Porcaro, C., Medaglia, M. T., & Krott, A. (2015). Removing speech artifacts from electroencephalographic recordings during overt picture naming. *NeuroImage*, *105*, 171-180.

R Development Core Team. (2016). R: A language and environment for statistical computing: Vienna, Austria, http://www.r-project.org.

Rabovsky, Milena, Schad, Daniel J, & Abdel Rahman, Rasha. (2016). Language production is facilitated by semantic richness but inhibited by semantic density: Evidence from picture naming. *Cognition, 146*, 240-244.

Riès, S. K., Fraser, D., McMahon, K. L., & De Zubicaray, G. I. (2015). Early and late electrophysiological effects of distractor frequency in picture naming: Reconciling input and output accounts. *Journal of Cognitive Neuroscience, 27*, 1936-1947.

Riès, S. K., Karzmark, C. R., Navarrete, E., Knight, R. T., & Dronkers, N. F. (2015). Specifying the role of the left prefrontal cortex in word selection. *Brain Lang, 149*, 135-147.

Roelofs, A. (2018). A unified computational account of cumulative semantic, semantic blocking, and semantic distractor effects in picture naming. *Cognition, 172*, 59-72.

Roelofs, A. (1992). A spreading-activation theory of lemma retrieval in speaking. *Cognition, 42*(1-3), 107-142.

Roelofs, A., Piai, V., Garrido Rodriguez, G., & Chwilla, D. J. (2016). Electrophysiology of cross-language interference and facilitation in picture naming. *Cortex, 76*, 1-16.

Rose, S.B., & Abdel Rahman, R. (2016). Cumulative semantic interference for associative relations in language production. *Cognition, 152*, 20-31.

Rose, S.B., & Abdel Rahman, R. (2017). Semantic similarity promotes interference in the continuous naming paradigm: Behavioral and electrophysiological evidence. Language, Cognition, & Neuroscience, 2:1, 55-68, DOI:10.1080/23273798.2016.1212081

Schnur, T. T., Schwartz, M. F., Brecher, A., & Hodgson, C. (2006). Semantic interference during blocked-cyclic naming: Evidence from aphasia. *Journal of Memory and Language, 54*(2), 199-227.

Schriefers, H., Meyer, A. S., & Levelt, W. J. M. (1990). Exploring the Time Course of Lexical Access in Language Production - Picture-Word Interference Studies. *Journal of Memory and Language, 29*(1), 86-102.

Schuhmann, T., Schiller, N. O., Goebel, R., & Sack, A. T. (2012). Speaking of Which: Dissecting the Neurocognitive Network of Language Production in Picture Naming. *Cerebral Cortex, 22*(3), 701-709.

Shitova, N., Roelofs, A., Schriefers, H., Bastiaansen, M., & Schoffelen, J. M. (2016). Using brain potentials to functionally localise Stroop-like effects in colour and picture naming: Perceptual encoding versus word planning. *PloS one, 11*(9), e0161052.

Strijkers, K., Costa, A., & Thierry, G. (2010). Tracking lexical access in speech production: electrophysiological correlates of word frequency and cognate effects. *Cerebral Cortex, 20*(4), 912-928.

Thorpe, S., Fize, D., & Marlot, C. (1996). Speed of processing in the human visual system. *nature, 381*(6582), 520.

Vieth, H. E., McMahon, K. L., & de Zubicaray, G. I. (2014a). Feature overlap slows lexical selection: Evidence from the picture–word interference paradigm. *The Quarterly Journal of Experimental Psychology*, 1-15.

Vieth, H. E., McMahon, K. L., & de Zubicaray, G. I. (2014b). The roles of shared vs. distinctive conceptual features in lexical access. *Frontiers in Psychology, 5*.

Vigliocco, G., Vinson, D. P., Damian, M. F., & Levelt, W. (2002). Semantic distance effects on object and action naming. *Cognition, 85*(3), B61-B69.

Vigliocco, G., Vinson, D. P., Lewis, W., & Garrett, M. F. (2004). Representing the meanings of object and action words: The featural and unitary semantic space hypothesis. *Cognitive Psychology*, *48*(4), 422-488.

Visser, M., Jefferies, E., Embleton, K. V., & Ralph, M. A. L. (2012). Both the middle temporal gyrus and the ventral anterior temporal area are crucial for multimodal semantic processing: distortion-corrected fMRI evidence for a double gradient of information convergence in the temporal lobes. Journal of Cognitive Neuroscience, 24(8), 1766-1778.

Vos, D. M., Riès, S., Vanderperren, K., Vanrumste, B., Alario, F. X., Huffel, V. S., & Burle, B. (2010). Removal of muscle artifacts from EEG recordings of spoken language production. *Neuroinformatics*, *8*(2), 135-150.

Wirth, M., Abdel Rahman, R. A., Kuenecke, J., Koenig, T., Horn, H., Sommer, W., & Dierks, T. (2011). Effects of transcranial direct current stimulation (tDCS) on behaviour and electrophysiology of language production. *Neuropsychologia*, *49*(14), 3989-3998.

Wohlert, A. B. (1993). Event-related brain potentials preceding speech and nonspeech oral movements of varying complexity. *Journal of Speech, Language, and Hearing Research*, *36*(5), 897-905.

Wong, A. W. K., Chiu, H. C., Wang, J., Cao, J., Wong, S. S., & Chen, H. C. (2017). An early locus of associative and categorical context effects in speech production: evidence from an ERP study using the picture–word interference paradigm. *Language, Cognition and Neuroscience*, *32*(10), 1305-1319.

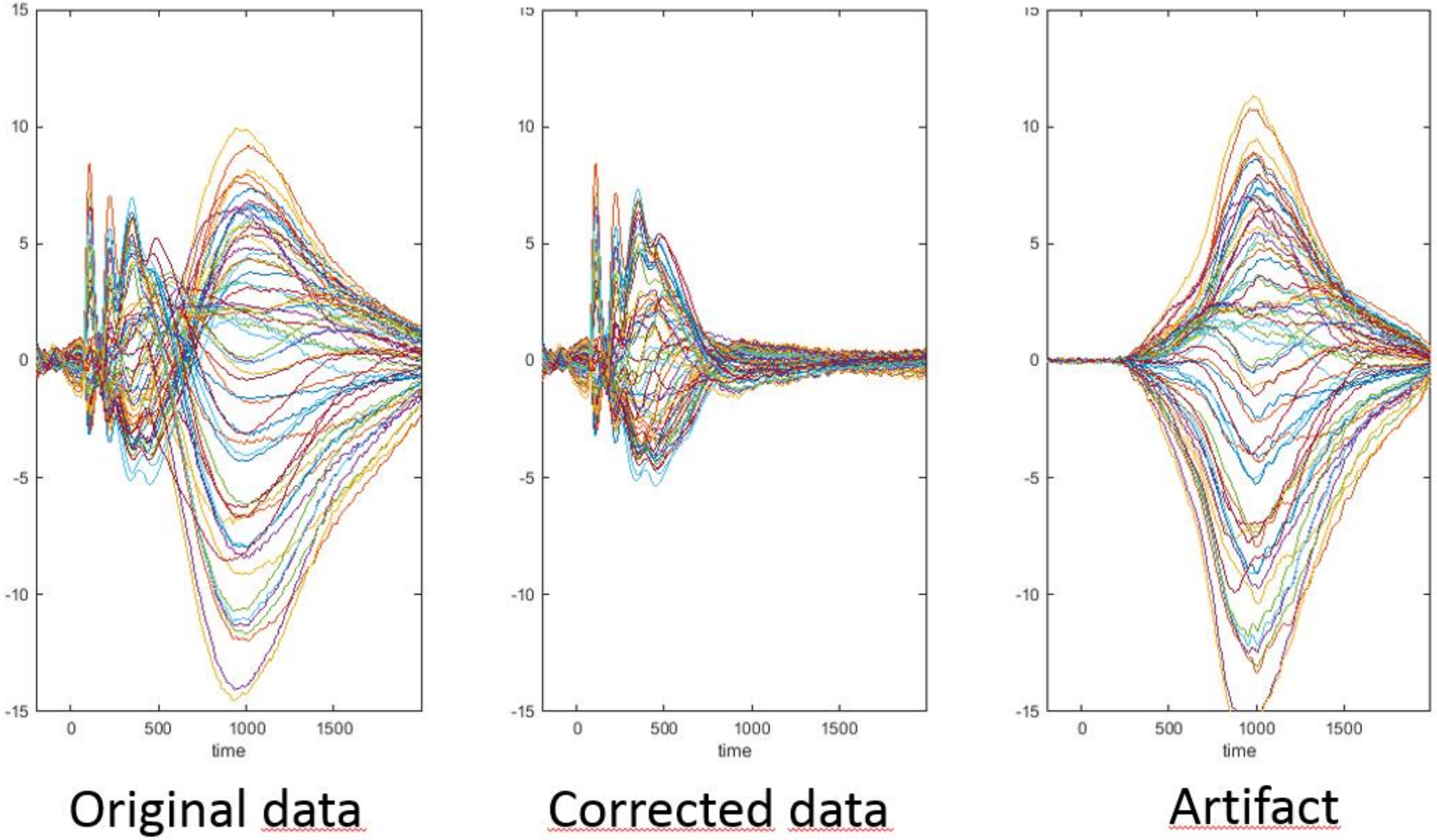

Figure 1. Left: Grand average ERP waveform before RIDE; middle: stimulus-locked component; right: response-locked component.

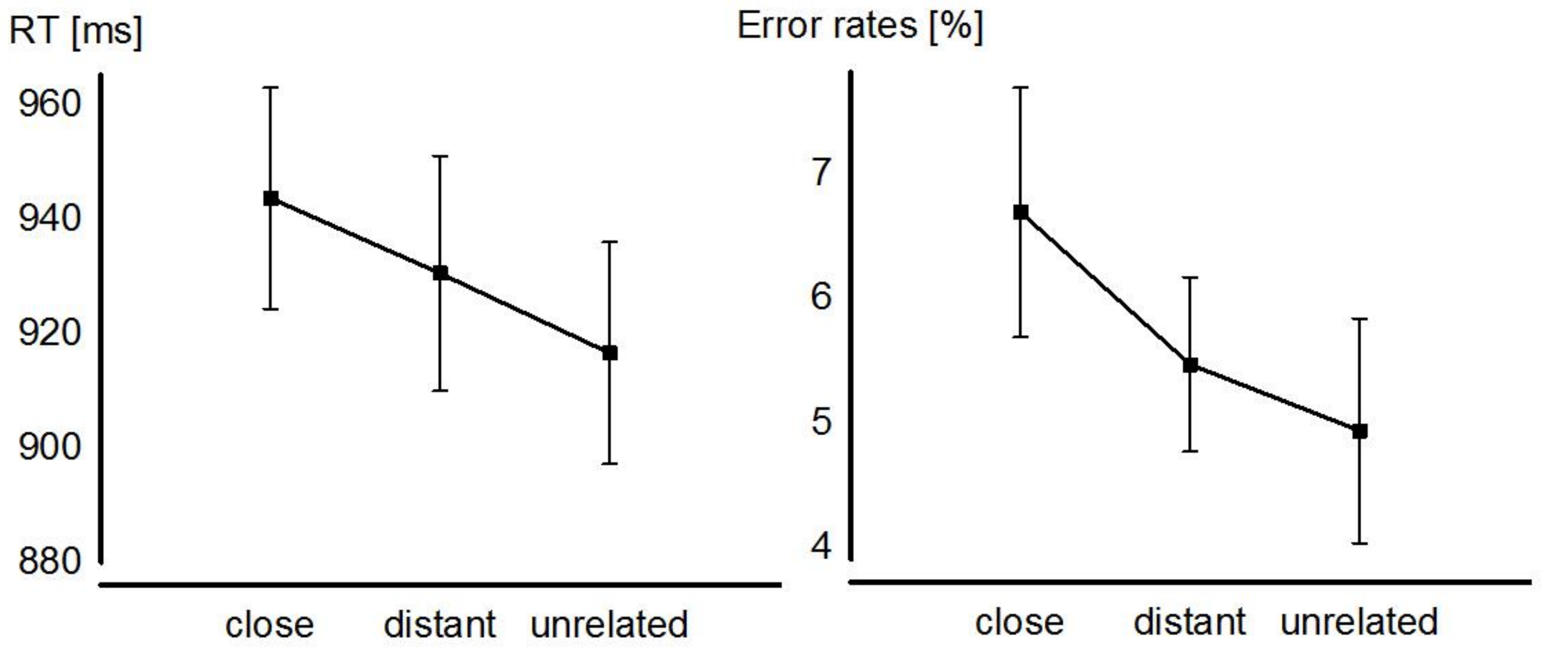

Figure 2: Mean naming latencies (left) and mean error rates (right) for each distractor condition. Error bars represent the standard error of the mean.

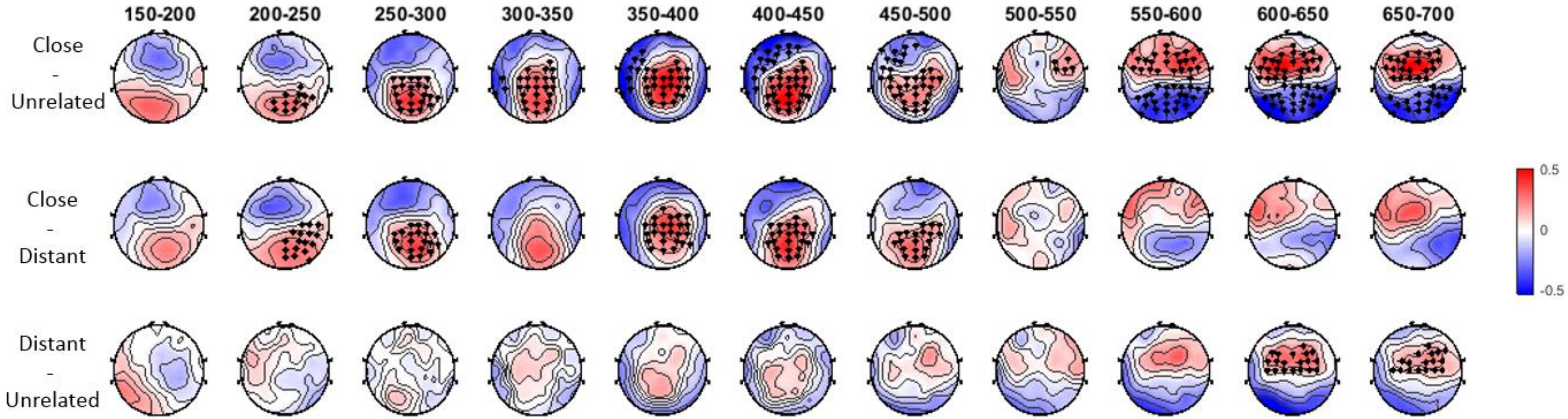

Figure 3: Topographies of the semantic distance effects. Maps show the difference between the semantically close vs. unrelated (top), close vs. distant (middle), and distant vs. unrelated (bottom) conditions.

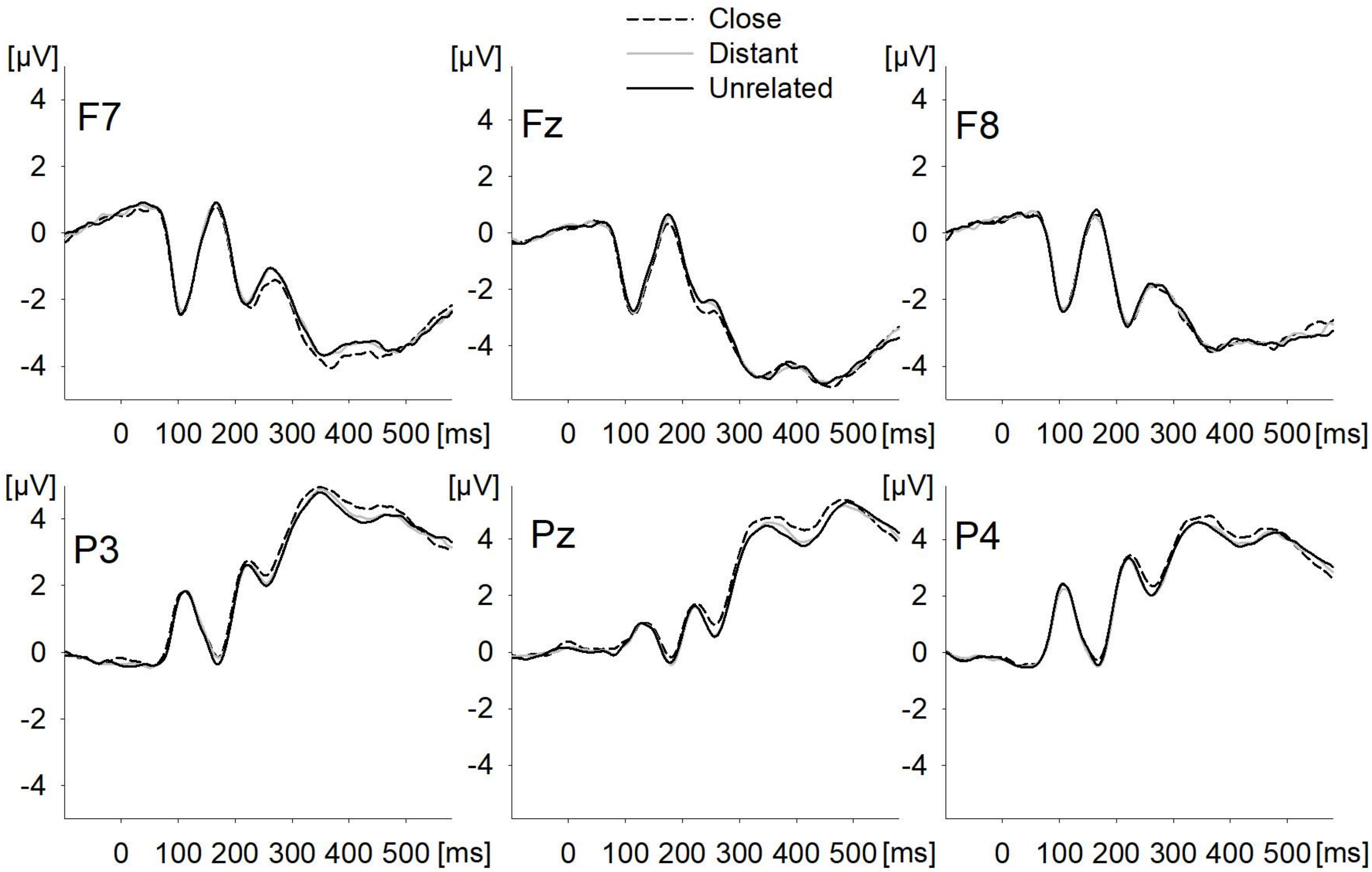

Figure 4: Effects of semantic distance on ERPs. Three electrodes from the frontal and posterior ROI are depicted.

Click here to access/download
Integral Supplemental Material (made available to referees)
integral supplement R2.pdf